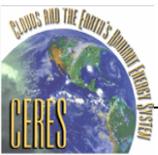


# Surface Clear Sky Correction in EBAF-Surface and Clear Sky Validation

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David Fillmore<sup>2</sup> and Tom Caldwell<sup>1</sup>

1. SSAI, Hampton, VA
2. UCAR, Boulder CO
3. NASA LaRC, Hampton, VA

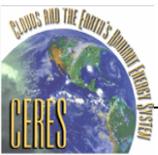


## **Two (Related) Topics**

**1a) Analyze the cloud vs clear atmosphere from an surface observational standpoint.**

**1b) Subsequently show EBAF-surface clear sky corrections.**

**2) Show how we use surface validation sites to establish regional uncertainty. (It requires a few assumptions.)**



# Clear vs Cloudy Atmospheres

## Consider the issue from surface observations:

DOE ARM/SGP C01 in Lamont  
OK, 2000-2018. (19 Years)

Use microwave radiometer  
column precipitable water. (PW)

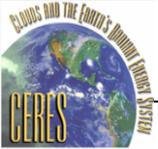
AERONET (Cimel sun  
photometer) aerosol optical  
depth. (AOD)

Cloud fraction from  
Long/Ackerman SWFA analysis.

(AERONET & SWFA implies  
daytime observations.)



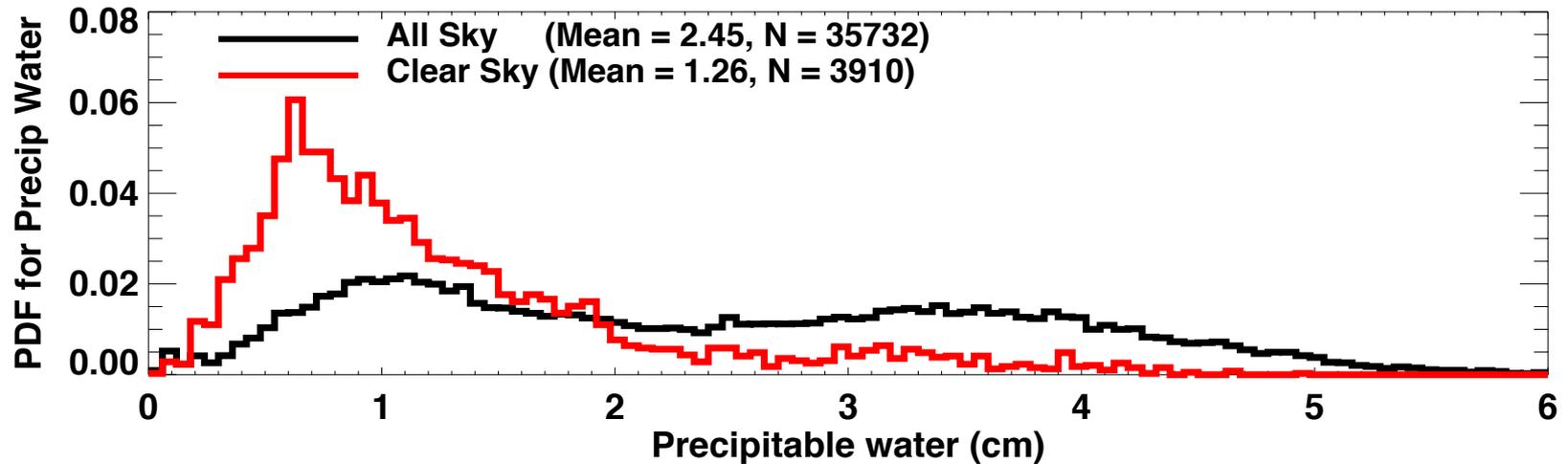
**Goal of next several slides is not to quantify but to describe:**



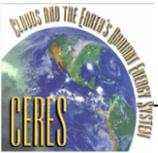
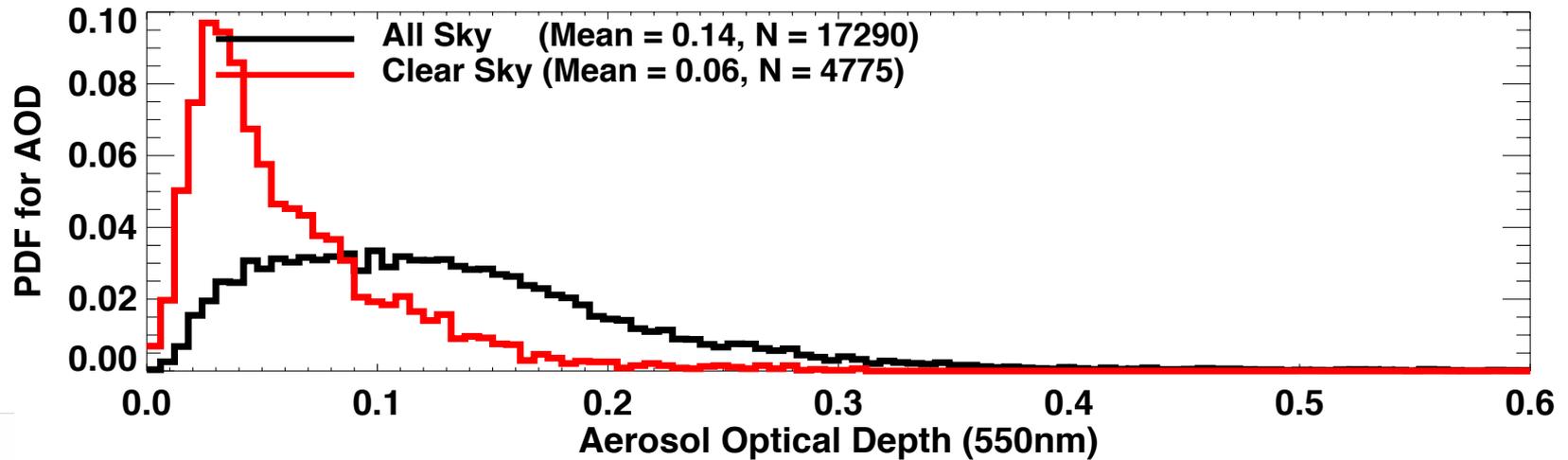
# Clear and All Sky PW & AOD

## Hour Average Distributions Observed at C01

### Precipitable Water



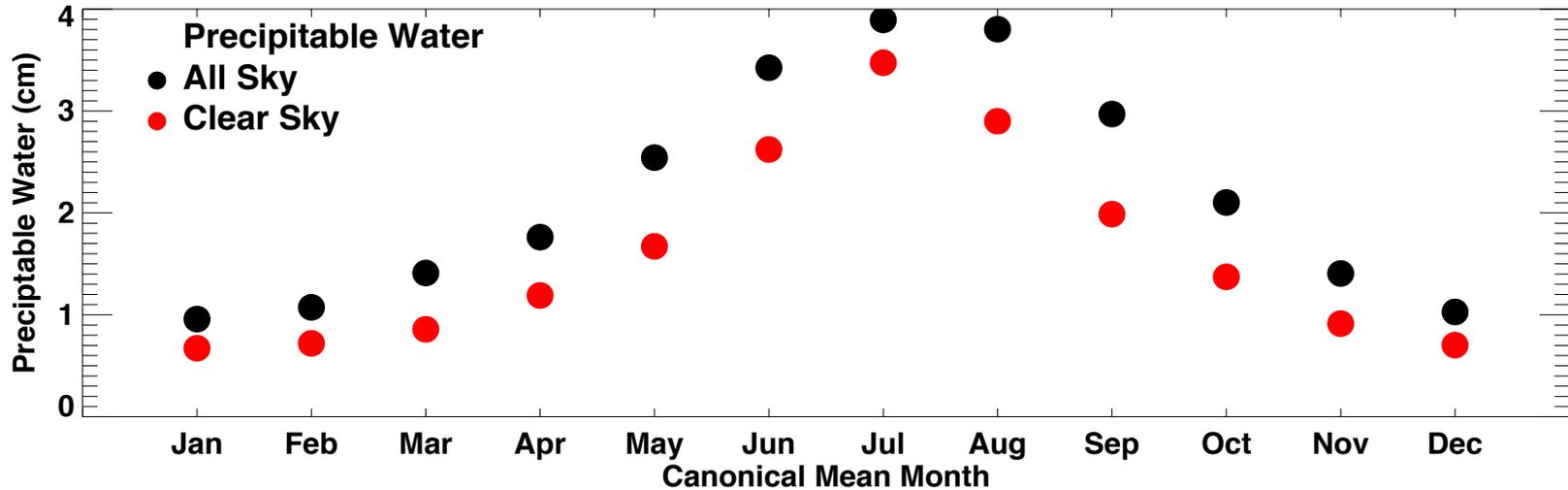
### Aerosol Optical Depth



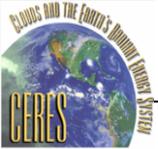
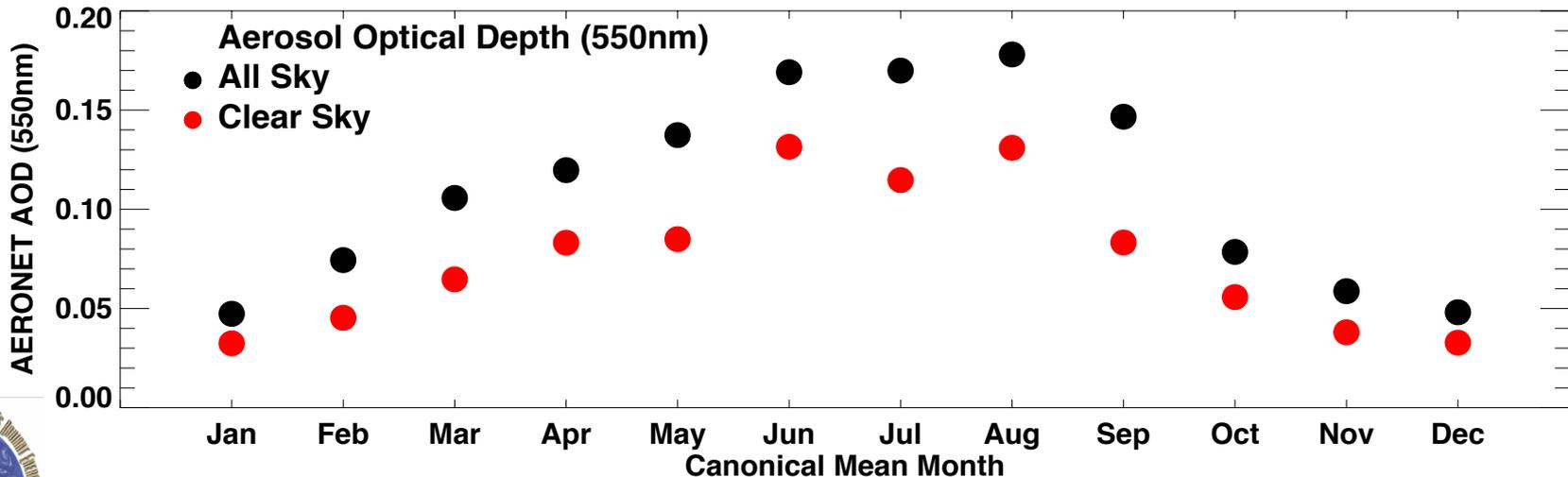
# Clear and All Sky PW & AOD

## Canonical Monthly Means Observed at C01

### Precipitable Water



### Aerosol Optical Depth



# Radiative Transfer Calculations

Demonstrate clear correction using Langley Fu & Liou radiative transfer code.

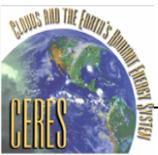
Use canonical monthly mean values of All and Clear Sky PW & AOD ( $\tau$ ) to define monthly clear and all sky atmospheres.

Use mid-latitude summer atmosphere, scaling PW to observed, aerosol type fixed to 'continental', divide by 2 since daytime only obs.

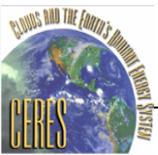
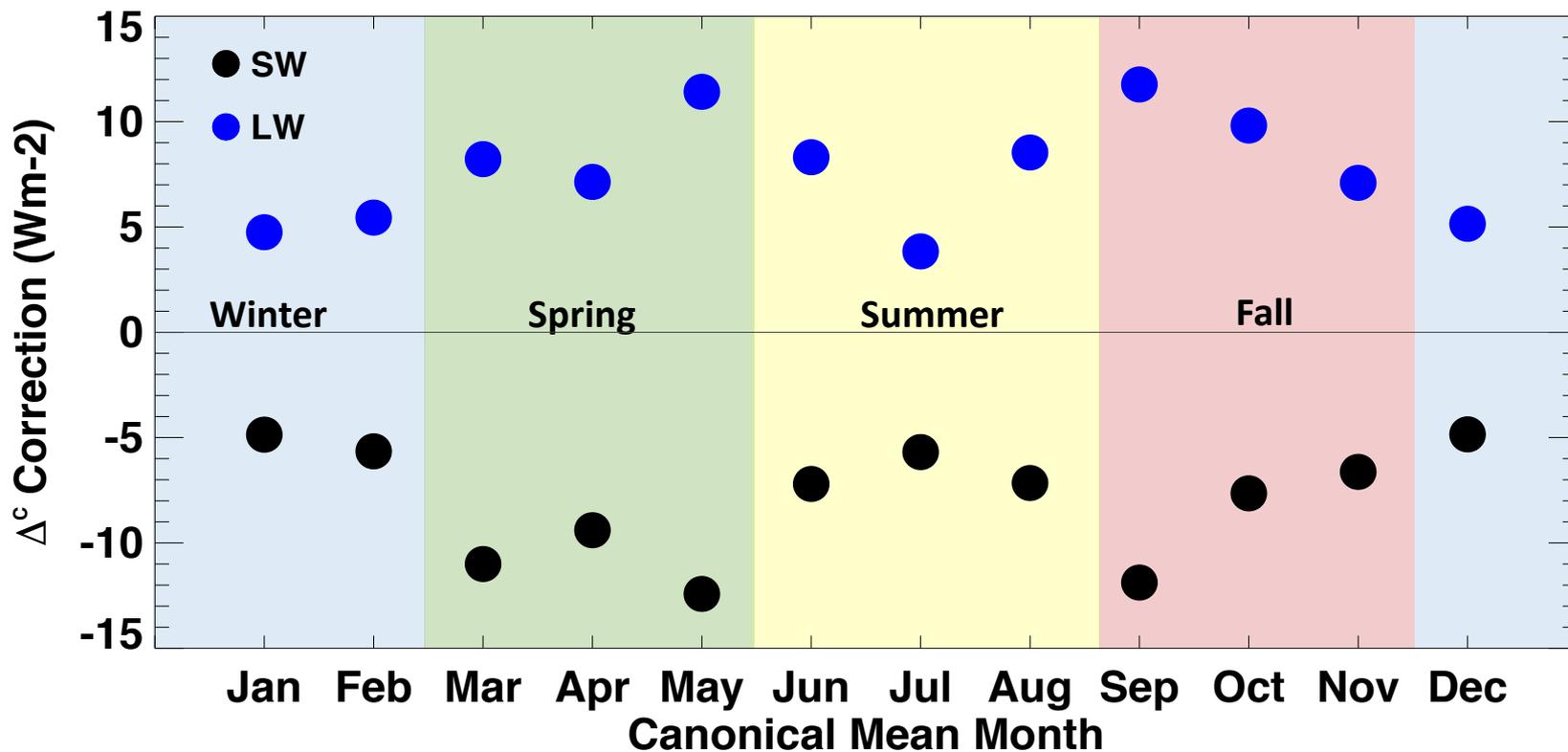
$$F_{\text{Clr}}(\text{PW}_A, \tau_A) \equiv \text{“Cloud Removed”}$$

$$F_{\text{Clr}}(\text{PW}_C, \tau_C) \equiv \text{“Clear” (Proxy for Obs Weighted)}$$

$$\Delta^C \equiv F_{\text{Clr}}(\text{CldRem}) - F_{\text{Clr}}(\text{ObsWgt})$$

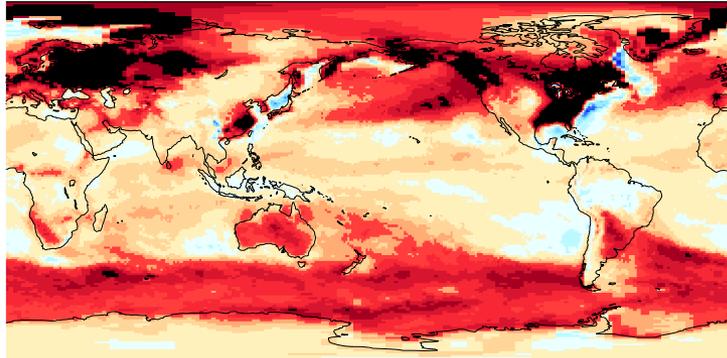


# $\Delta^c$ , Clear Correction (At ARM/SGP/C01 site)



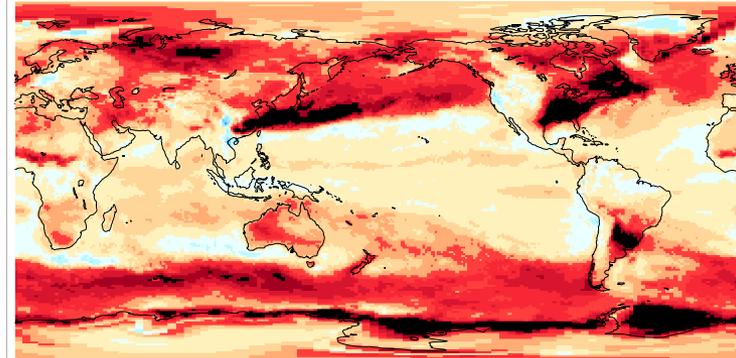
# $\Delta^C$ , Surface LW Down Monthly Correction

Jan (Avg = 3.8 Wm<sup>-2</sup>)



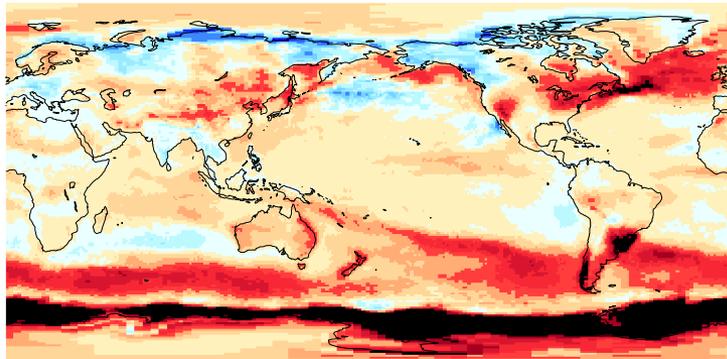
Sfc LW CldRem-ObsWgt (Wm<sup>-2</sup>)

Apr (Avg = 3.5 Wm<sup>-2</sup>)



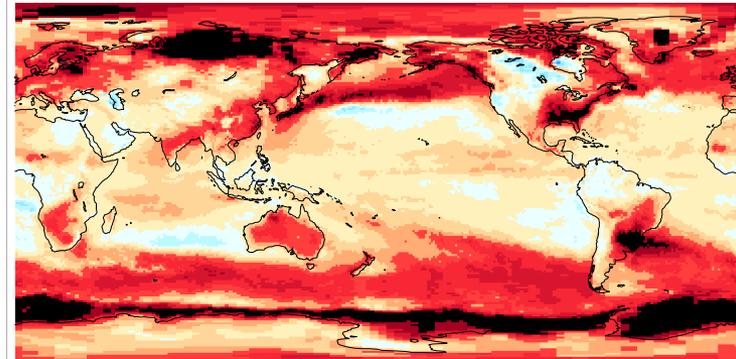
Sfc LW CldRem-ObsWgt (Wm<sup>-2</sup>)

Jul (Avg = 2.5 Wm<sup>-2</sup>)



Sfc LW CldRem-ObsWgt (Wm<sup>-2</sup>)

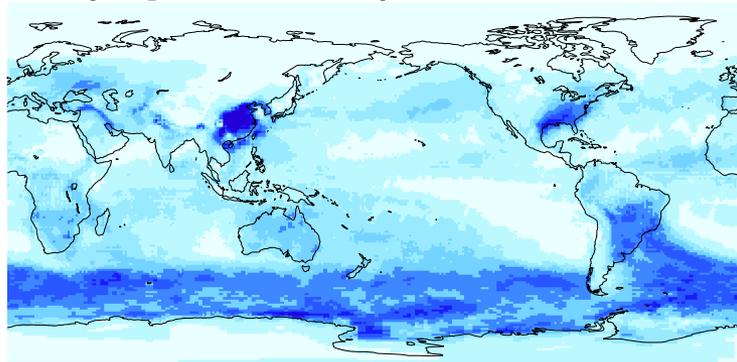
Oct (Avg = 3.6 Wm<sup>-2</sup>)



Sfc LW CldRem-ObsWgt (Wm<sup>-2</sup>)

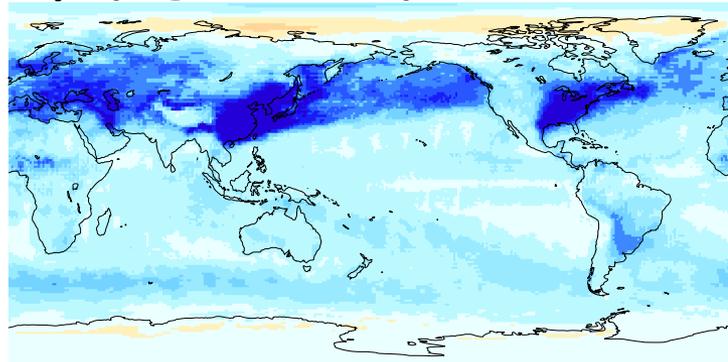
# $\Delta^C$ , Surface SW Down Monthly Correction

Jan (Avg =  $-2.4 \text{ Wm}^{-2}$ )



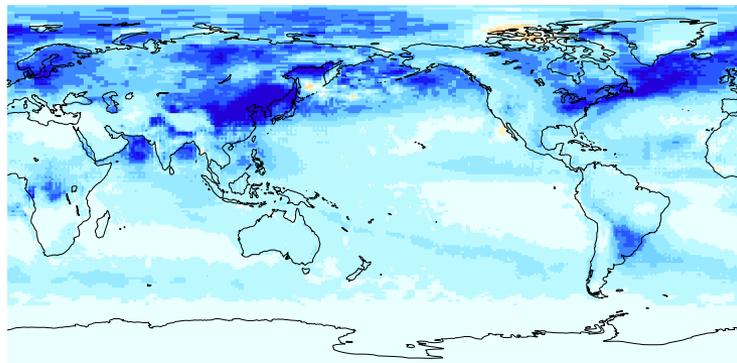
Sfc SW CldRem-ObsWgt ( $\text{Wm}^{-2}$ )

Apr (Avg =  $-2.4 \text{ Wm}^{-2}$ )



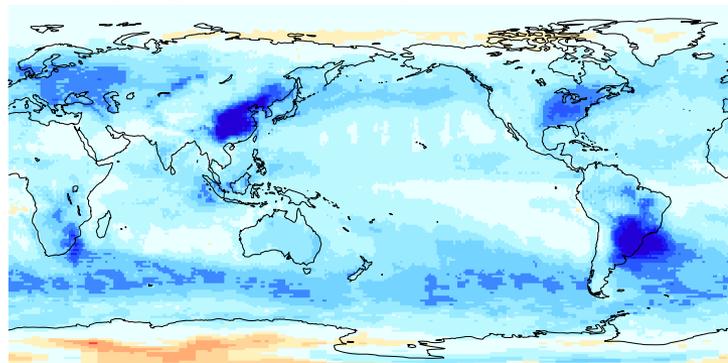
Sfc SW CldRem-ObsWgt ( $\text{Wm}^{-2}$ )

Jul (Avg =  $-2.1 \text{ Wm}^{-2}$ )

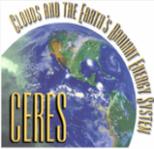


Sfc SW CldRem-ObsWgt ( $\text{Wm}^{-2}$ )

Oct (Avg =  $-2.2 \text{ Wm}^{-2}$ )

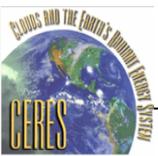
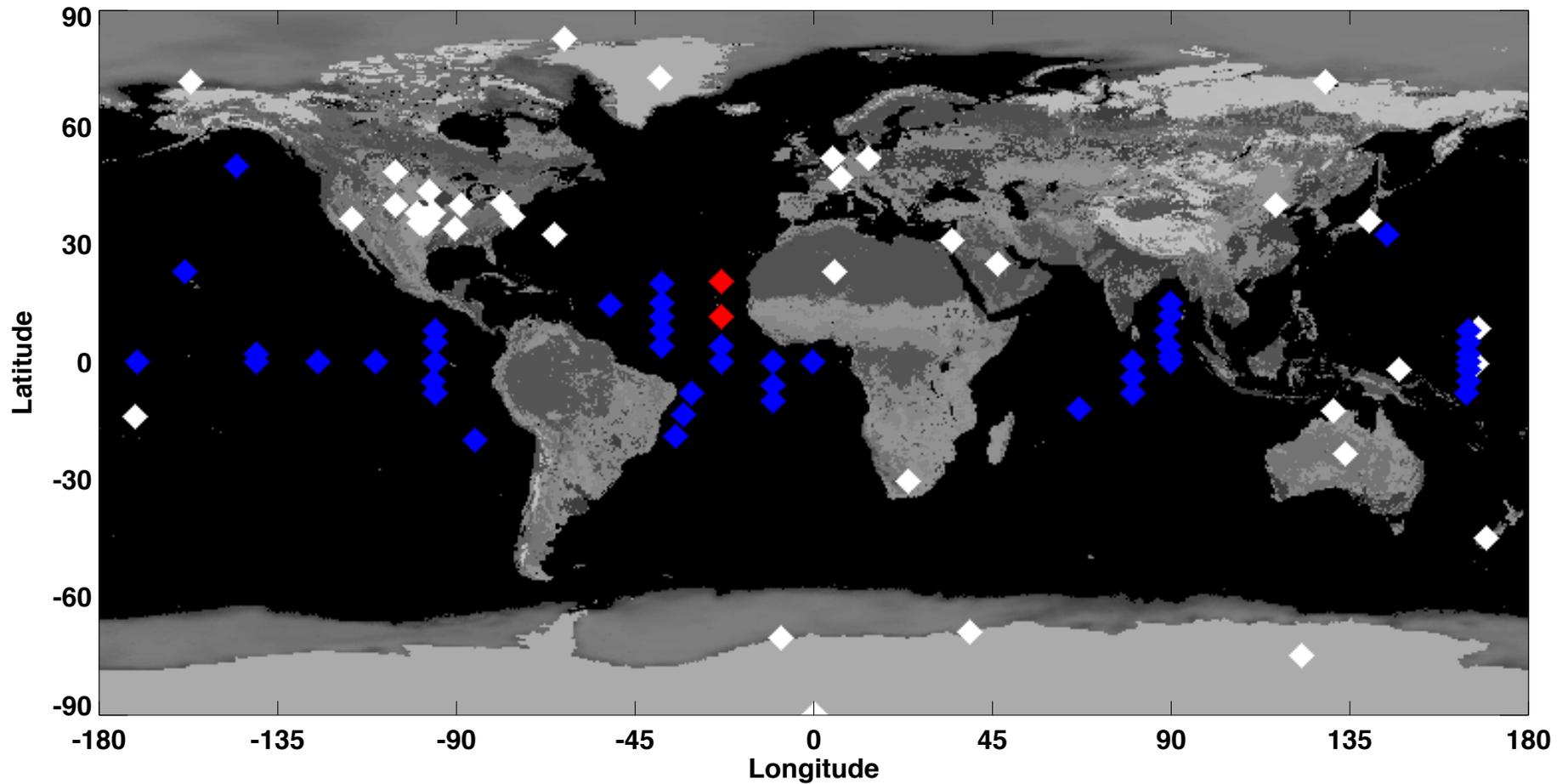


Sfc SW CldRem-ObsWgt ( $\text{Wm}^{-2}$ )



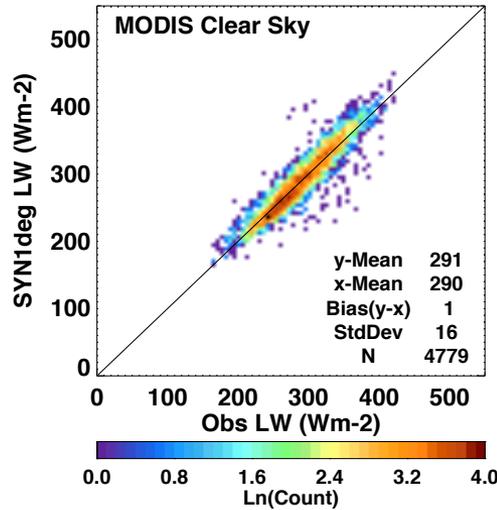
# Regional Uncertainty of Clear Calculations

## Using Surface Observation Sites

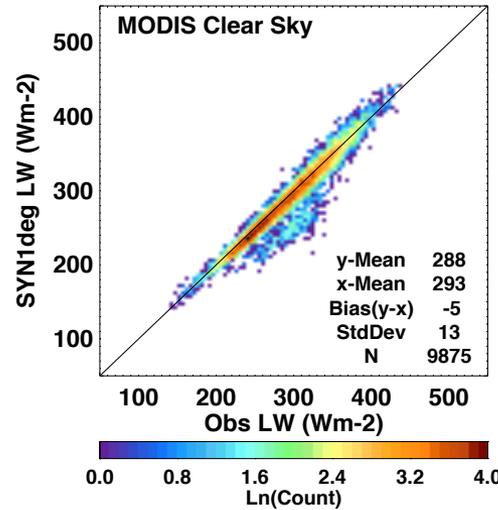


# Clear sky (MODIS only) hourly comparisons.

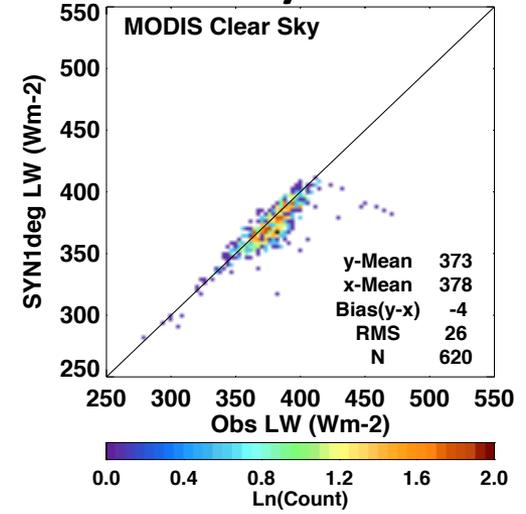
## BSRN LW



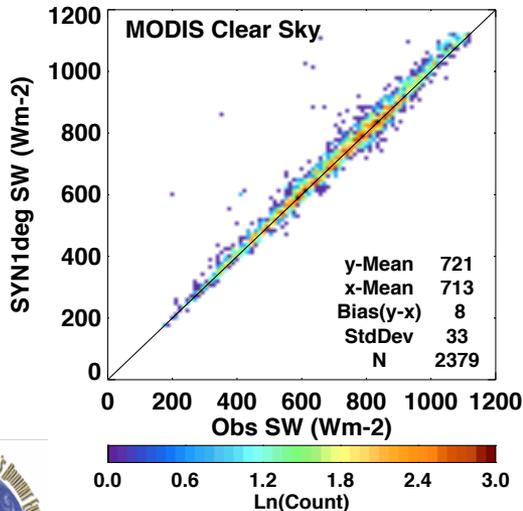
## SURFRAD LW



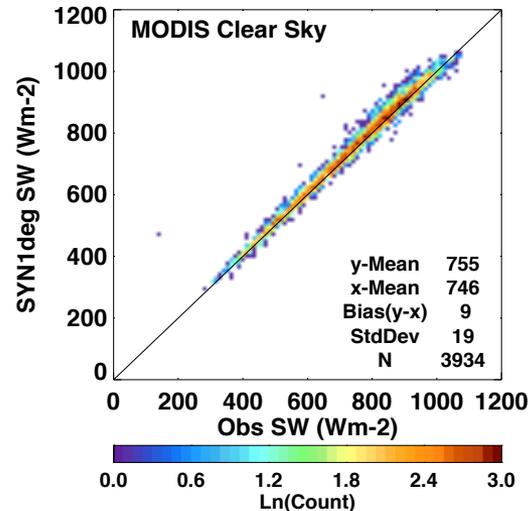
## Buoy LW



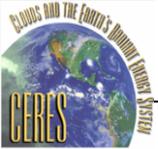
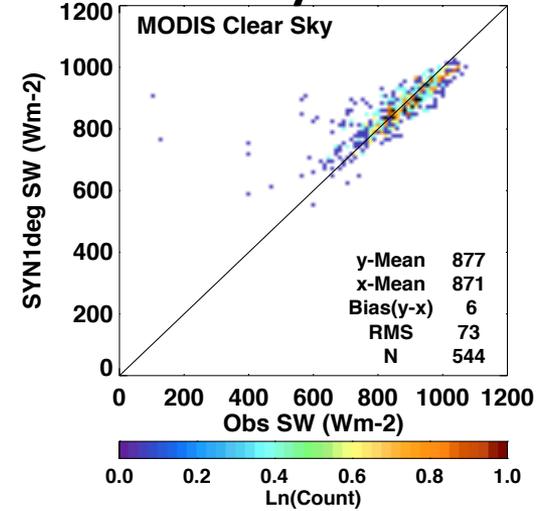
## BSRN SW



## SURFRAD SW



## Buoy SW



Temporally, the data are relatively sparse but we assume randomly distributed throughout each month over time, **thus they approximate 1 independent sample per day.**

(All equations for both Longwave and Shortwave.)

$B = \text{Bias (Calculation - Observation)}$

$\sigma = \text{Standard deviation}$

$$S = \frac{\sigma}{\sqrt{30}} \text{ Standard Error}$$

$\bar{x} = \text{Mean Observed Flux Down}$

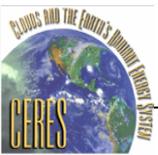
$$B^r = \frac{B}{\bar{x}} \text{ Relative Bias} \quad S^r = \frac{S}{\bar{x}} \text{ Relative Standard Error}$$

$B^r$  and  $S^r$  are multiplied by global mean land(ocean) flux down  $\overline{F^\downarrow}$

$$RMSD = \sqrt{(B^r * \overline{F^\downarrow})^2 + (S^r * \overline{F^\downarrow})^2}$$

$$\overline{RMSD}_{Land} = \sum_i^{N_{groups}} RMSD_i * w_i \quad (w_i = \#sites \text{ in a group})$$

$$\overline{RMSD}_{Ocean} = \sqrt{(B_o^r * \overline{F_o^\downarrow})^2 + (S_o^r * \overline{F_o^\downarrow})^2}$$

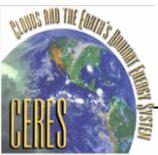


*Land(ocean) RMSD's are weighted by approximate land(ocean) area.*

$$\overline{RMSD}_{Regional} = \sqrt{(\overline{RMSD}_{Land} * W_{land} + \overline{RMSD}_{Ocean} * W_{ocean})^2 + (\epsilon_{inst})^2}$$

$\epsilon_{instruments} \approx 5 \text{ Wm}^{-2}$

	Surface Uncertainties $\text{Wm}^{-2}$	
	All-Sky	Clear-Sky
LW down	9	8
LW up	15	15
LW Net	17	17
SW down	14	6
SW up	11	11
SW Net	13	13
SW + LW Net	20	21



# Summary

Surface observations over 19 years of clear and cloudy conditions show the difference in the ambient atmosphere for each case.

Precipitable water and aerosol optical depth differ in the mean by nearly 50%. This result is maintained throughout the year.

RT model demonstrate the clear sky correction necessary when 'cloud removed' clear sky calculations are done.

Globally LW clear sky correction is generally positive such that removing a cloud leaves behind a moister, warmer atmosphere. (Global averages  $\sim 3.5 \text{ Wm}^{-2}$ )

In the SW the removing clouds from an RT calculation leaves the atmosphere almost always less transmissive. (Global averages  $\sim -2.2 \text{ Wm}^{-2}$ )

Using surface comparisons of clear sky observations and calculated fluxes we demonstrated how clear sky regional uncertainties are determined.

LW  $\sim 8 \text{ Wm}^{-2}$  and SW  $\sim 6 \text{ Wm}^{-2}$ .

